Safe & Sustainable Water Resource Research

Water Quality Focus on Nutrients and Nutrient enhanced Coastal Acidification and Hypoxia

Office of Research and Development
National Health and Environmental Effects Research Laboratory

Why the focus on nutrients?

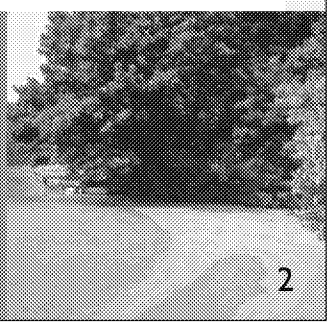
Excess nutrient loading continues to be the most prevalent cause of water quality impairment.

Tools are needed to support a response to the threat of nutrient enrichment…

that are locally applicable.

Nutrients are a "wicked problem"

- **Multiple scales**
- **Numerous Sources**
- **Effects may be far from source**
- **Impacts are often indirect**



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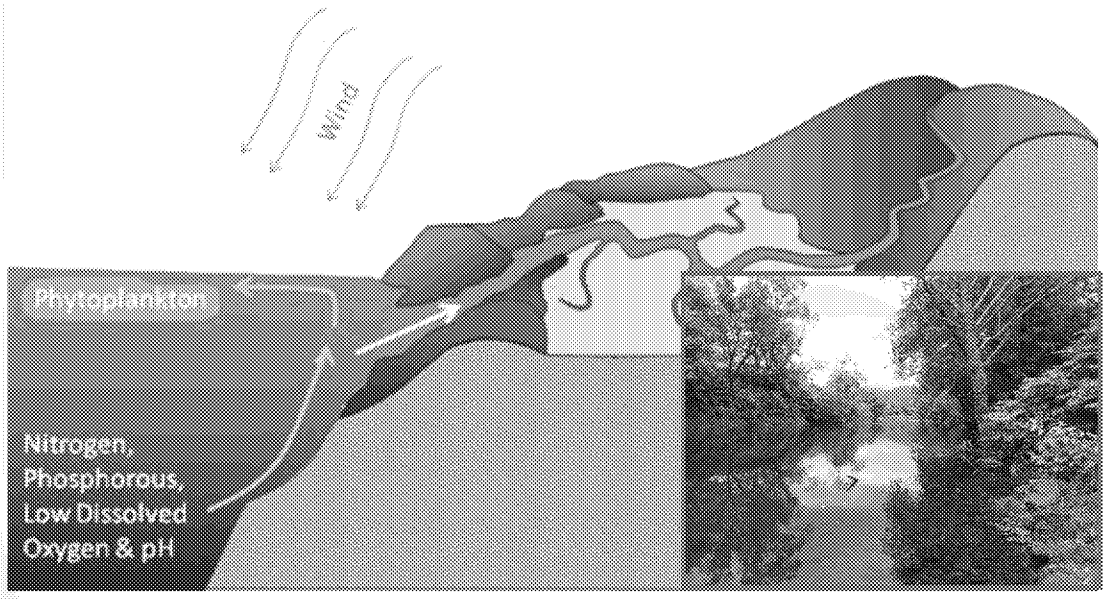
Tools are need to support a coherent, effective and sustainable response.
"Wicked" problems are difficult or impossible to solve because of incomplete, contradictory, and changing requirements that are often challenging to recognize

Multiple geographic scales (local, regional, national)
Multiple sources (e.g., fossil fuel combustion, agricultural, water treatment)
Effects may be far from source (e.g., hypoxia, harmful algal blooms, acidification)

Wicked problem
not like toxics

States adoption of NNC hasn't progressed as planned esp for estuarine and coastal waters.

Locally Relevant Tools



WED Capabilities for Nutrient Enhanced Acidification & Hypoxia Research

Diverse expertise: Oceanographer, chemist, ecologists, modelers

Seawater equipped facilities – able to manipulate seawater nutrient & CO_2 levels (and resulting pH levels) in experimental chambers and monitor responses.

State-of-the-art field instrumentation –continuously monitor CO_2, pH and nutrient levels.

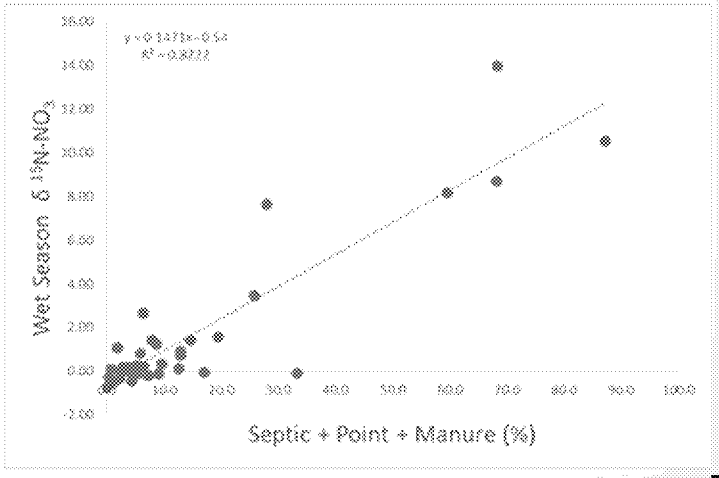
Integrated Stable Isotope Research Facility (ISIRF) – to identify the major sources (air, land and water) of carbon and nutrients that cause acidity.

Research and Development Agreement (CRADA) with Oregon State University – Experts on acidification impacts

Collaboration with State and Tribal shellfish managers – monitoring & attribution of acidification drivers

Tools to Identify Nutrient Sources

- Stable isotopes of macroalgae and dissolved inorganic nitrogen
- Development of indicator from Alaska to Mexico
- Watershed analysis of land use/land cover drivers



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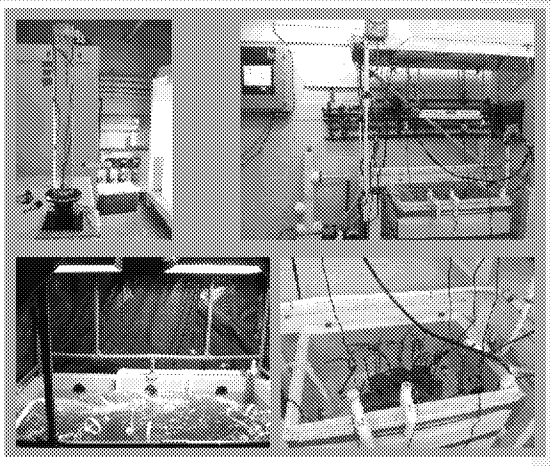
Development of Stable isotope at a variety of scales from local estuary; to larger scale.
Localized interpretation
Elements can exist in both stable and unstable (radioactive) forms. Most elements of biological interest (including C, H, O, N, and S) have two or more stable isotopes, with the lightest of these present in much greater abundance than the others. Atoms of the same atomic numb`er but different atomic weights are called isotopes, differences in amount of neutrons.
Among stable isotopes the most useful as biological tracers are the heavy isotopes of carbon and nitrogen

Nutrient Impacts & Indicators

We conduct:

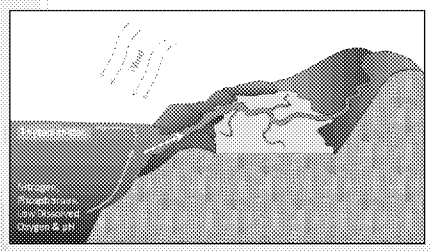
- Field, laboratory & modeling studies.
- Evaluate & develop nutrient indicators
  - Seagrass
  - Macroalgae
  - Phytoplankton
  - Epiphytes
  - Sediment organic content

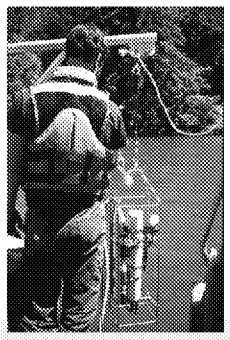


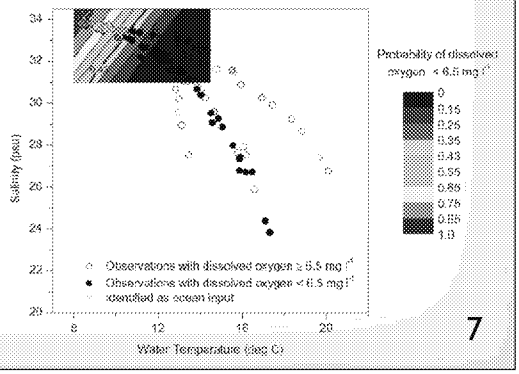
Tools to Assess Compliance

- Ocean influences water quality
- May exceed water quality criteria & eutrophication indicators
- Distinct thermal & saline signatures
- User-friendly tool

- Goal: Prevent incorrectly listing water body as impaired.





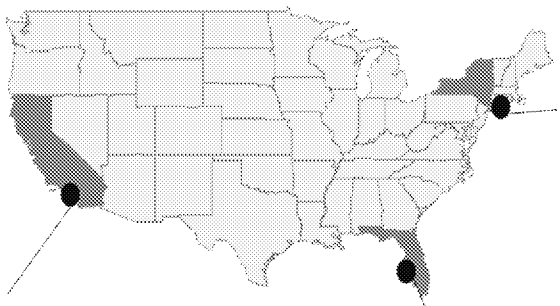


Tool calculates the probability that exceedance of water quality standards (such as dissolved oxygen) is related to ocean condition.
Add photo of measuring O2 or nutrients?

Identifying pathways associated with managing nonpoint sources of nutrients into coastal ecosystems

Factors of Success:

- Implementation of a diverse array of Best Management Practices, that targeted the greatest sources of nutrient loading.
- The most effective practices utilized artificial wetlands and grassy swales for biotic uptake of nitrogen and phosphorus.



Peconic Estuary

1. Reduced stormwater runoff
2. Majority of sources groundwater & atmospheric
3. Water & habitat quality still declining

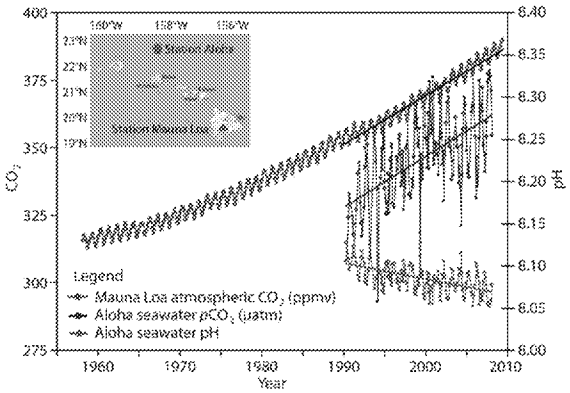
Newport Bay

1. Reduced agriculture fertilizer runoff
2. Used artificial wetlands
3. Restoration occurred within 20 years

Roberts Bay

1. Reduced residential fertilizer runoff
2. Used artificial wetlands
3. Restoration occurred within 15 years

Coastal Acidification: An Emerging Water Quality Issue



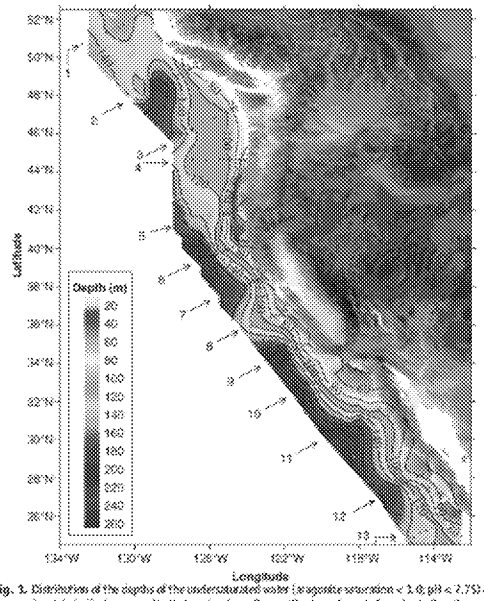


Fig. 1. Distributions of the depths of the undersaturated water (aragonite saturation < 1.0; pH < 7.75) on the continental shelf of western North America from Queen Charlotte Sound, Canada, to San Gergonio Baja California Sur, Mexico. On transect line 5, the corrosive water reaches all the way to the surface in the inshore waters near the coast. The black dots represent station locations.

- Acidification has increased.
- Current conditions were not predicted to occur until 2050.

Feely et al. (2008). Evidence for upwelling of corrosive "acidified" water onto the continental shelf. *Science* 320.

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Acidification of nearshore waters has increased in spatial extent along west coast.
Presently, we are experience conditions that weren't expected until 2050.

The Seattle Times

Shellfish at risk: Puget Sound becoming acidified

The waters of Puget Sound and Hood Canal are becoming more acidified as a result of rising carbon dioxide from industries, power plants and vehicles. Scientists from the University of Washington and the National Oceanic and Atmospheric Administration warn that the shifting water chemistry could damage the region's shellfish industry.

The Seattle Times

Lucrative crab industry in danger

SEACHANGE

The Seattle Times

Oysters in deep trouble: Is Pacific Ocean's chemistry killing sea life?

Oyster larvae have been dying by the billions. Scientists suspect it's a sign that carbon dioxide is dramatically affecting the ocean — and if they're right, it could push Washington into the center of the debate about the future of the seas.

SEACHANGE

Vital part of food web dissolving

The Seattle Times

Are Oysters Doomed?

Don't believe in climate change? Talk to a clam digger.

Los Angeles Times

Oceans' rising acidity a threat to shellfish — and humans

By Kenneth R. Weiss, October 6 2012

As carbon dioxide continues to build up in the atmosphere as a result of burning fossil fuels, the seas absorb much of it. The full effects have yet to be felt.

The New York Times

Some See Clean Water Act Settlement Opening New Path to GHG Curbs

Lots of press, resonating with the public and state governments (e.g., govenors). PNW is at the center of this issue.

The first sign of biological impacts in the PNW appeared within the last decade. From 2005 to 2009, two commercial shellfish hatcheries in Washington and Oregon suffered massive die-offs of Pacific oyster larvae. During that same timeframe, wild Pacific oysters in areas of the Pacific Northwest where they have naturalized failed to successfully reproduce. The failed natural reproduction coupled with significant hatchery production problems in two of the main West Coast shellfish hatcheries threatened the viability of much of the West Coast shellfish industry, which is dependent upon hatcheries and wild reproduction for seed.

Initially, the die off of larvae in hatcheries was thought to be caused by blooms of a strain of bacteria called Vibrio tubiashii flourishing in oxygen-starved dead zones. As hatchery operators, researchers, and others worked to understand the source of the problem, an alternate theory emerged: that the ocean's absorption of anthropogenic CO_2 was increasing the concentration of hydrogen ions and reducing the pH and the dissolved carbonate ion concentration, as well as the aragonite and calcite saturation states of coastal marine waters, which was having a significant and adverse effect on larval oysters' ability to form shells.

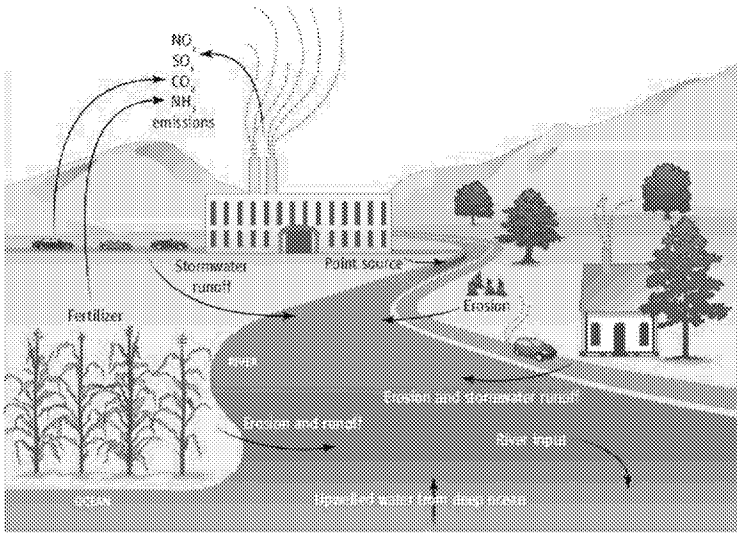
POLICYFORUM

OCEANS

Mitigating Local Causes of Ocean Acidification with Existing Laws

Even as global and national efforts struggle to mitigate CO_2 emissions, local and state governments have policy tools to address "hot spots" of ocean acidification.

R. P. Kelly,[1]*† M. M. Foley,[1]* W. S. Fisher,[2] R. A. Feely,[3] B. S. Halpern,[4] G. G. Waldbusser,[5] M. R. Caldwell[1]



Contributors to ocean acidification. In addition to global atmospheric CO_2, this figure depicts the major local (within 100 km) sources contributing to coastal ocean acidification.

"Local & state governments have both the authority and motive to address many stressors that drive or exacerbate acidification conditions"

↓

Clean Water Act

Technical Support to Region 10

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27 MAY 2011 VOL 332 SCIENCE www.sciencemag.org

Some of the potential causes are changes in upwelling, nutrient loading, changes in freshwater inflow, atmospheric emissions, etc.
http://www.sciencemag.org/content/332/6033/1036.full
Although increasing anthropogenic CO2 inputs drive acidification at global scales, local acidification disproportionately affects coastal ecosystems and the
communities that rely on them. We describe policy options by which local and state governments—as opposed to federal and international bodies—can reduce these local and
regional "hot spots" of ocean acidification.

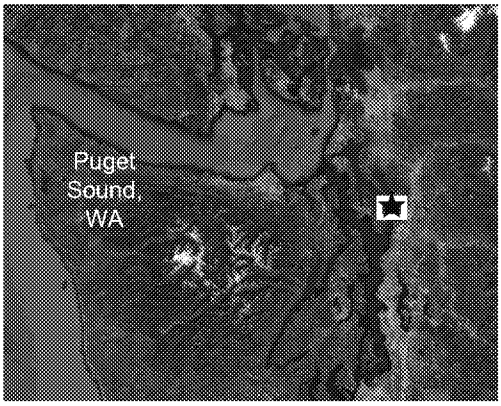
Several studies document acidification hot spots, patches of ocean water with significantly depressed pH levels relative to historical
baselines occurring at spatial scales of tens to hundreds of square kilometers. These coastal hot spots may be due to nonuniform changes in circulation and biological processes, and precipitation runoff in concert with globally increased atmospheric CO2. Freshwater inputs, pollutants, and soil erosion can acidify coastal waters at substantially higher rates than atmospheric CO2 alone.

These non-atmospheric inputs can have particularly large consequences when they coincide with biotic phenomena [e.g., spawning
events or abiotic processes, such as upwelling events that bring low-pH water to nearshore areas. Additional local phenomena—
such as sulfur dioxide precipitation, hypoxia, eutrophication , and both emissions and runoff from acidic
fertilizers—can intensify these localized hot spots. These impacts are likely to be magnified when combined with other stressors in
the coastal ocean, including overfishing, habitat destruction, temperature increases, and nonacidifying pollution.

As global and national efforts to mitigate CO2 emissions struggle to gain traction, smaller-scale
actions become increasingly important. In the United States, for example, local and state governments have both the authority and motive to address many stressors that drive or exacerbate acidification conditions. This runs contrary to the widely held

perception
that acidification cannot be addressed at the scale of local (e.g., municipal and county) or regional (state, multistate, and territorial)
Jurisdictions.

Toward a Unified Understanding of Coastal Acidification Processes in Puget Sound



1. Characterize the drivers of carbonate chemistry experienced by nearshore shellfish beds.

2. Quantify the relative contributions of natural and anthropogenic nitrogen sources to these nearshore areas.

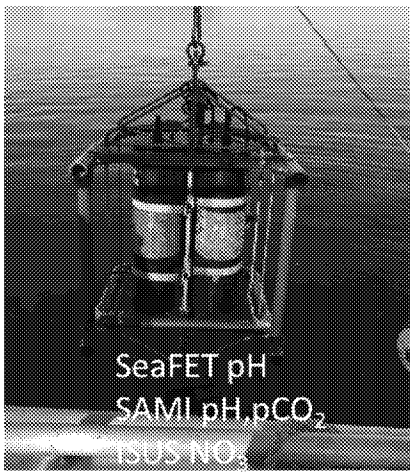
Collaborators:

USGS science for a changing world

Oregon State University OSU

Pacific Northwest National Laboratory

Department of Ecology State of Washington



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Large land-based nutrient inputs (river, agricultural and wastewater)
Ecologically important for salmon & shellfish harvests

Summer, winter, and spring intensive sampling (July 2015 – April 2016)

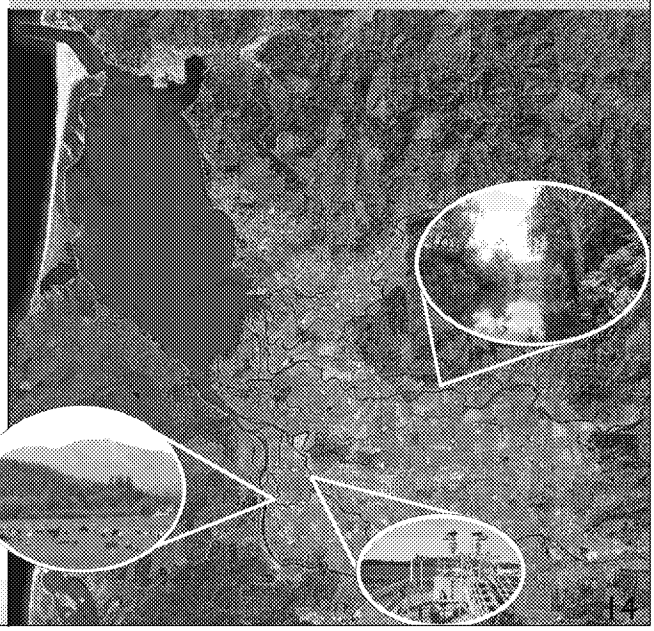
- *In situ* instrumentation
- TCO_2, pCO_2, nutrients, chl *a*
- Isotopes (NO_3, NH_4, DIC, POM)

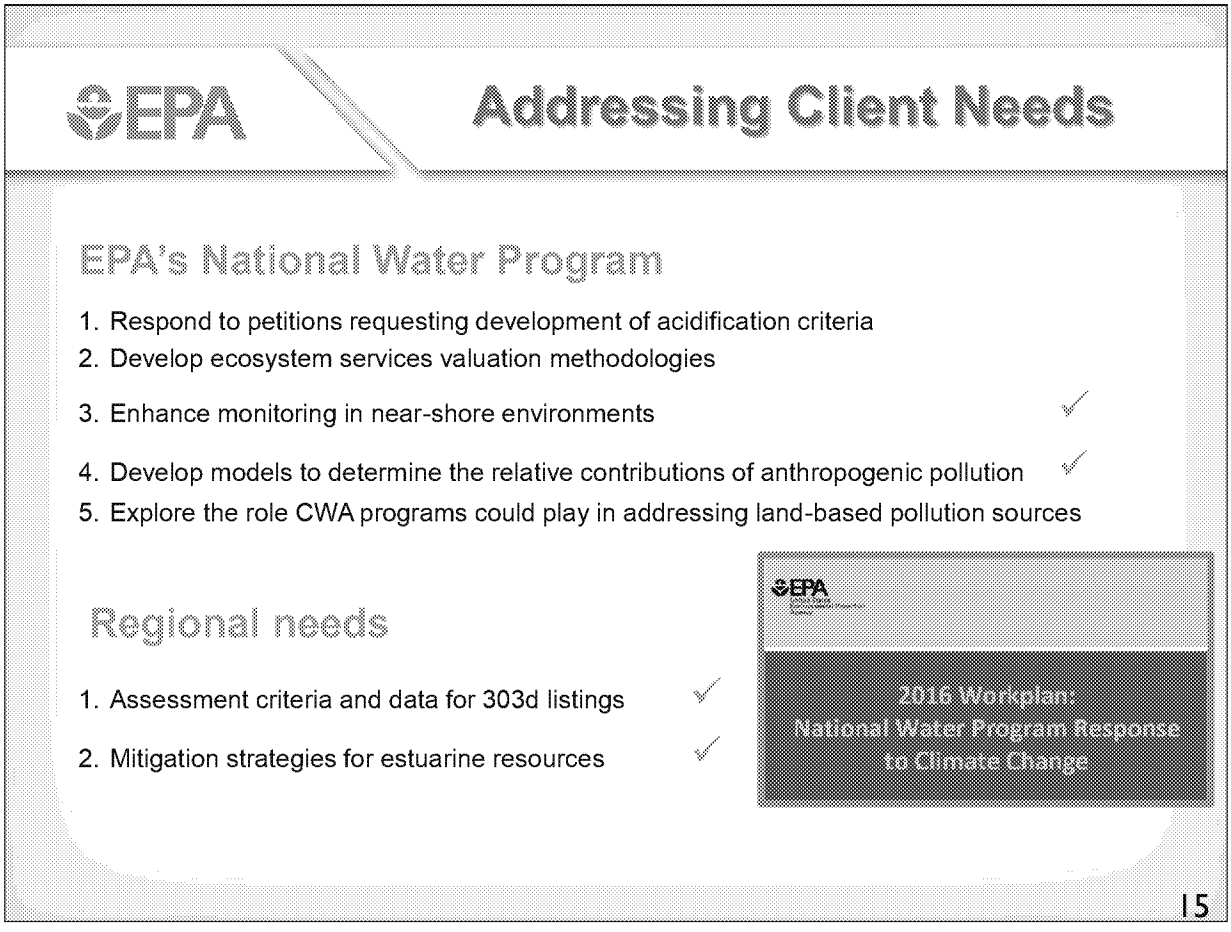
- Develop models
- Use model to identify key factors influencing carbonate chemistry.
- Evaluate the effect of changing atmospheric CO_2 levels

Role of Local Drivers on Coastal Acidification in Tillamook Estuary

Tillamook Estuaries Partnership
A National Estuary Project

- Identifying nutrient sources.
  - Microbial source tracking.
- Role of local drivers on carbonate chemistry & oxygen dynamics.
- Role of nutrients in enhancing acidification.
  - Mesocosm experiments
- Models to predict impacts of climate change on water quality.





Emerging priority issue with HQ and Regions and has made the priority list for EPA's ocean and coastal priorities.
https://www.epa.gov/sites/production/files/2016-04/documents/final_2016_nwp_climate_workplan.pdf
https://www.epa.gov/sites/production/files/2015-04/documents/2016-2017_nwpg_final.pdf